Economic dispatch of Jeneponto thermal power plant for primary energy efficiency

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Abstract. Economic dispatch is a method to compute the amount of power that must be generated from each generator units to meet a specific load while minimizing its operating costs. This study performed economic dispatch for the Jeneponto Thermal Power Plant, in the Jeneponto Regency, South Sulawesi Province, Indonesia by using the Lagrange multiplier method. The results of this study showed that by performing economic dispatch, it is effective in minimizing the fuel cost compared to the existing dispatch. The overall savings that can be obtained for this case study is 4.5% for the specific case study.

1. Introduction

A good electrical energy system should be safe, economical, efficient, effective, high quality and reliable [1, 2]. This means that in the generation and distribution of electrical energy, it must be done economically and rationally. Nevertheless, there are many obstacles in the electrical power operation that must be handled to achieve the above objectives caused by the random nature of electrical power systems. The operating conditions will change following the variation in load and/or discharge of any network equipment on the system unintentionally and may cause deviation of operation [3, 4]. Most utilities applied the usage of reactive power compensating devices to maintain deviation in reactive powers [5].

Jeneponto Thermal Power Plant located in the Jeneponto Regency, South Sulawesi Province is one of the IPP power plants for the Southern Sulawesi power system which provides power to the system for both base and peak loads [6]. The Jeneponto power plant is a coal based power plant. Like other thermal power plants, the Jeneponto power plant also faces a problem in terms of fuel costs that tend to increase over time. Meanwhile, the fuel costs account for the majority of overall plant operating costs, therefore it is essential for optimizing fuel costs which will result in more economical generating operations than before [7, 8]. Hence, efforts should be made to minimize the production cost of operating the thermal power plants or primary energy efficiency.

Minimizing the operating cost of the plants means optimizing the work of the power plant units, in terms of scheduling the power generation of the existing plants properly [9]. Generators with the smallest operating cost should be maximized and the plants with the greatest cost should be less used.

The economic dispatching of power plants is done by observing the input and output of the plant, i.e. how much fuel is needed to generate energy and how much it will cost in accordance with the capacity of the units. This is done regardless of the existing loading conditions.

2. Economic Dispatch

Economic dispatch is an attempt to determine the amount of power that must be supplied from each unit of generators to meet specific loads with the aim of minimizing the operating costs of generation with operational parameter constraints [10-13]. Economic dispatch computation between the generating units in a power plant is mathematically equal to the economic dispatch between the power plants, but for scheduling between the power plants, it is necessary to calculate the transmission losses as an additional constraint to obtain accurate results [14-16]. Further works in economic dispatch considers the possible transmission congestion problems [17, 18].

Generally, the input-output characteristics of the thermal generator are approximated by a second order polynomial function as,

$$H_i = \alpha_i + \beta_i P_{ti} + \gamma_i P_{ti}^2 \tag{1}$$

Where: H_i is the input of thermal generating fuel to unit *i* (liter/hour), P_{ti} is the thermal generator output of unit *i* (MW) and $\alpha_i,\ \beta_i,\ \gamma_i$ are the input-output constant of the thermal unit *i*.

Understanding economic dispatching of thermal power plants is the economic sense because the cost is required on the input side for every generator, hence for the total power output generated by all the generators requires total cost amount of all generators [19, 20]. The financial problem is how to regulate and manage the output of each plant in such a way as to obtain the minimum total input cost of all generators. This can be done by optimizing the total cost of all generating inputs in the power system to the power output and for that purpose, a mathematical model must be made to perform optimization calculations. The method used in the handling of economic dispatch is the Lagrange multiplier method. The Lagrange multiplier (or λ-iteration) method has been commonly used in finding a solution for solving economic dispatch [21, 22], because of its effectiveness to accomplish optimal fuel cost among thermal generators [23].

The objective equation is formed from the total cost of fuel inputs from each plant:

$$F_T = F_1 + F_2 + F_3 + \cdots + F_N = \sum_{i=1}^{N} F_i(P_i) \tag{2}$$

With constraints:

$$\sum_{i=1}^{N} P_i = P_r$$

or

$$\Psi(P_1, P_2, P_3, \ldots, P_N) = P_r - \sum_{i=1}^{N} P_i = 0 \tag{3}$$

From Eq. 3, then the Lagrange function is developed as

$$L = F_T + \lambda \Psi \tag{4}$$

Where λ is the Lagrange multiplier factor. Eq. 4 is the generator's output function and optimum condition can be obtained by doing the Lagrange equation equal to zero.

$$\nabla L = 0$$

$$\nabla F_T(P_i) + \lambda \nabla \Psi(P_i) = 0$$
$$\frac{\partial F_T(P_i)}{\partial\,(P_i)} + \lambda\left(\frac{P_r}{P_i} - \frac{\partial P\,(P_i)}{\partial (P_i)}\right) = 0 \quad (5)$$
$$\frac{\partial F_T(P_i)}{\partial\,(P_i)} + \lambda\,(0+1) = 0$$
$$\frac{\partial F_T(P_i)}{\partial\,(P_i)} = \lambda$$

Since $F_i = F(P_i)$, then the partial differential equation can be written as,

$$\frac{dF_i}{dP_i} = \lambda \quad (6)$$

Where i is the i^{th} generator

Eq. 6 determines the minimum operating cost condition from all thermal units within a power system, with the fuel cost incremental for all units equal to λ, hence Eq. 6 becomes the optimum requirement. Because the generator operation is constrained by its minimum and maximum power output, P_{min} and P_{max}, respectively, hence to obtain the optimum dispatch of the operating units, the equation that can be used are:

$$\frac{dF_i}{dP_i} = \lambda$$
$$P_{min} \leq P_i \leq P_{max}$$
$$\sum_{i=1}^{N} P_i = P_r$$

3. Results and Analysis

Jeneponto Thermal Power Plant in Jeneponto Regency is a coal based thermal power plant and has power capacity of 2 x 125 MW [24]. It is one of the IPP's in the Southern Sulawesi power system which provides power to the system for both base and peak loads. Fig. 1 shows the power generation dispatching at the Jeneponto Thermal Power Plant for every hour in a day with its fuel cost for every hour, while Fig. 2 informs the optimal dispatch for the same total load. Then in Fig. 3, the operating costs between the current dispatch and economic dispatch are compared. In general, the results of the economic dispatch offers smaller fuel cost compared to the existing dispatch. The percentage of cost savings for this optimization can be seen in Fig. 4. The overall savings that can be obtained for this case study is 4.5%. From this study, it is recommended for the Jeneponto Thermal Power Plant to perform economic dispatch for their daily operation to save fuel costs. By using the Lagrange method for economic dispatch, this can provide guidance for the Jeneponto Thermal Power Plant for their daily generation dispatching.

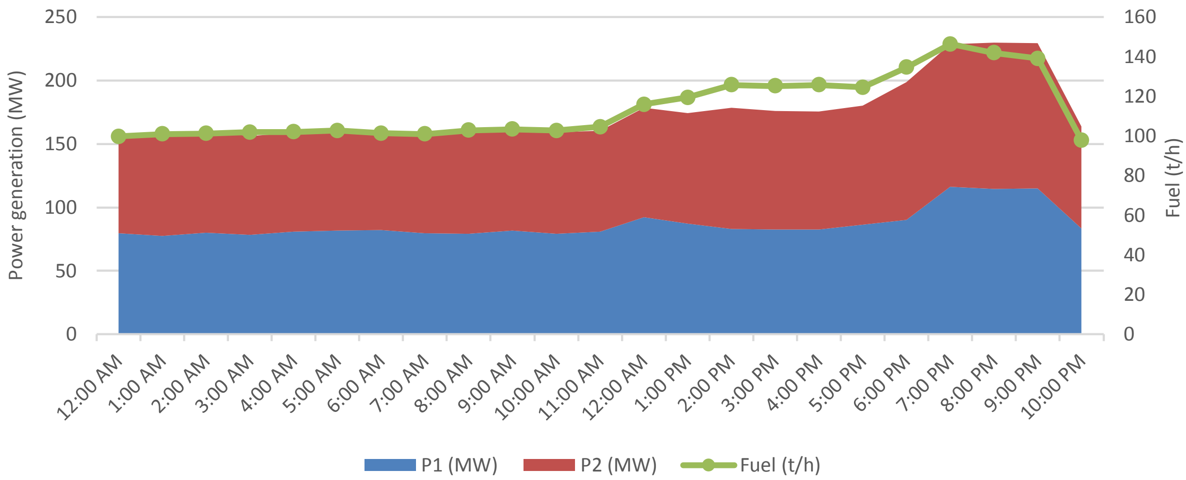

Figure 1. Current dispatch at the Jeneponto Thermal Power Plant

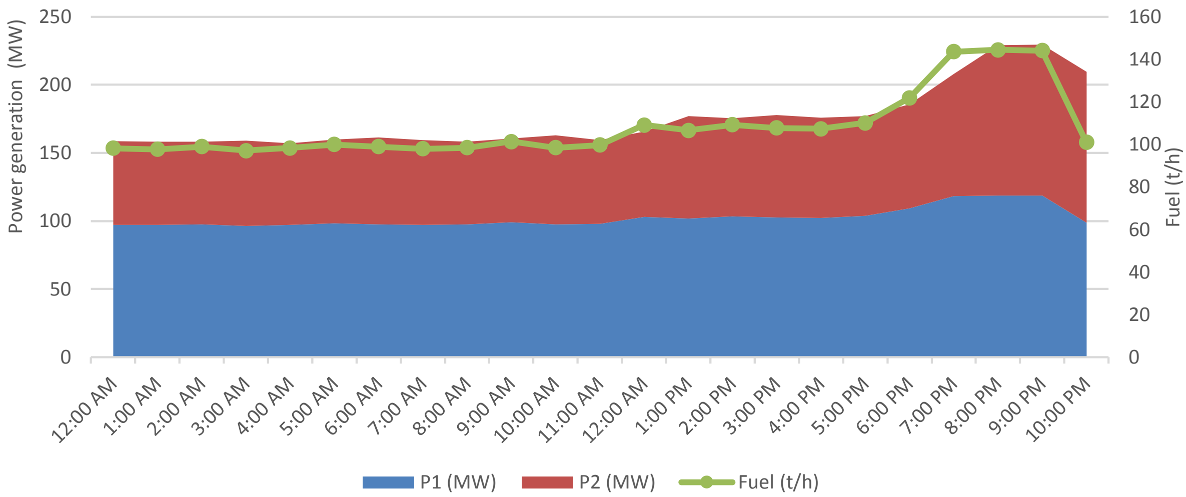

Figure 2. Economic dispatch results for the Jeneponto Thermal Power Plant

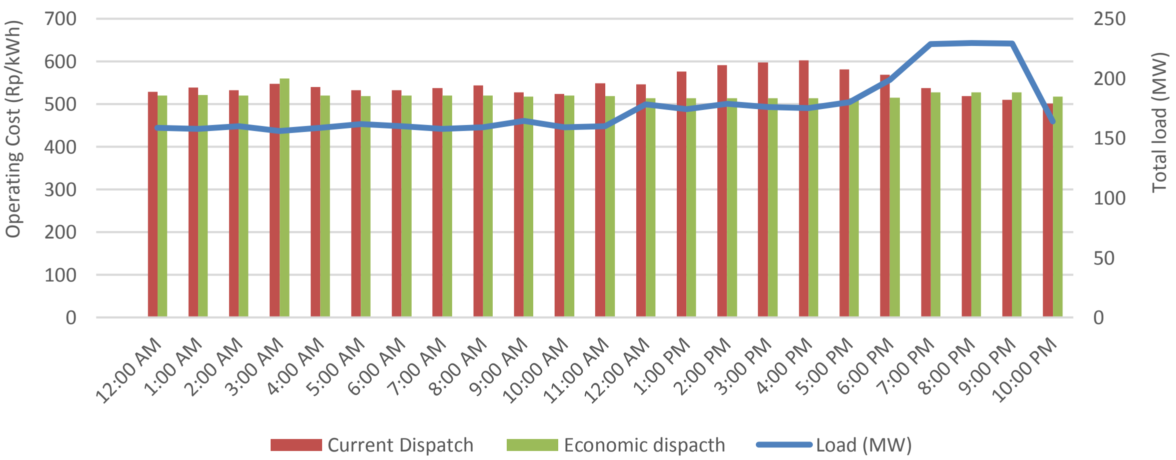

Figure 3. Comparison of operating costs between current dispatch and economic dispatch

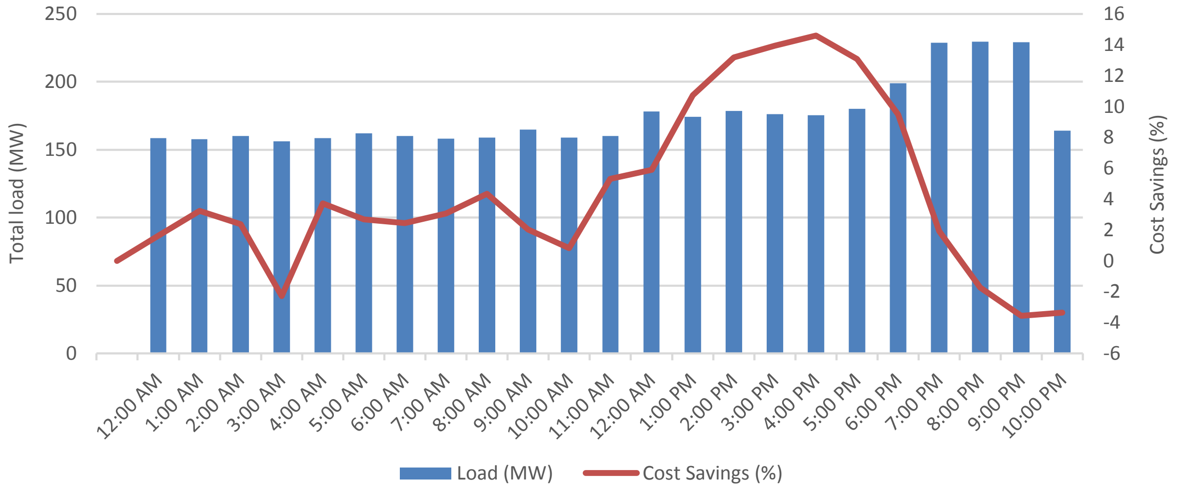

Figure 4. Cost savings for each total load

4. Conclusions

This paper presents economic dispatch for the Jeneponto Thermal Power Plant with a power capacity of 2 x 125 MW. The results of this study confirms that fuel cost can be minimized by performing economic dispatch with Lagrange multiplier method. The overall savings that can be obtained for this case study is 4.5%. Therefore, it is recommended for the Jeneponto Thermal Power Plant to perform economic dispatch for their daily operation to save fuel costs.

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